

**Learning Text**

**Mortar Testing**

# Mortar Testing

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## Introduction

This learning text considers the topic of testing fresh and hardened mortar. The reasons for testing are discussed, followed by a synopsis of the test methods. A glossary of terms is also included.

Two standards are applicable to the testing of mortar, namely:

- BS EN 1015 - Methods of test for mortar for masonry (a multi part standard)
- BS 4551 - Methods of test for mortar.

Testing is generally undertaken for four principal reasons:

- To evaluate conformity with a specification or Standard
- To control or monitor the consistency of a product or process
- To examine performance under project specific conditions
- To investigate problems and resolve disputes

There are four main forms of testing which can be undertaken:

- i) Production Control Testing:** Construction materials and component producers often undertake testing to monitor and control their production process. This should not be confused with conformity evaluation, even though the same test methods may be used, as their purpose is entirely different.
- ii) Performance Testing:** Performance testing involves for example prism or cube testing, testing hardened mortar specimens to determine the water vapour permeability or concrete pipes for leaks. Performance testing is becoming more important as new product standards are being written in terms of a performance requirement rather than being based on a recipe.
- iii) Compliance Testing:** This involves testing materials or components against the requirements of the contract specification or Standard.
- iv) Forensic Testing:** This involves investigating problems in order to resolve disputes e.g. chemical analysis of hardened mortar for cement or air content.

The results of production control and/or performance testing may be used for the evaluation of conformity.

The volume of standards and other regulatory documents that relate to the conduct of testing and calibration is increasing on a National, European and International scale. Within the United Kingdom, laboratories engaged in testing and calibration may seek accreditation from The United Kingdom Accreditation Service (UKAS). Accreditation may be sought for a single test or for a wide range of tests.

Laboratories wishing to be accredited by UKAS are required to submit a quality manual to UKAS for approval. The quality manual has to be drafted to comply with the requirements of BS EN ISO/IEC 17025:2000 - General requirements for the competence of testing and calibration laboratories. Each test method requires individual accreditation.

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### BS EN 1015 : Methods of Test For Mortar For Masonry

This is a multi part Standard, the individual parts that have been published are listed in Table 1. There are some gaps in the sequence of part numbers, this has occurred because numbers were allocated for the drafting of test methods that have subsequently been withdrawn from the standardization work programme.

Part 1	Determination of particle size distribution (by sieve analysis).
Part 2	Bulk sampling of mortars and preparation of test mortars.
Part 3	Determination of consistence of fresh mortar (by flow table).
Part 4	Determination of consistence of fresh mortar (by plunger penetration).
Part 6	Determination of bulk density of fresh mortar.
Part 7	Determination of air content of fresh mortar.
Part 9	Determination of workable life and correction time of fresh mortar.
Part 10	Determination of dry bulk density of hardened mortar.
Part 11	Determination of flexural and compressive strength of hardened mortar.
Part 12	Determination of adhesive strength of hardened rendering and plastering mortars on substrates.
Part 17	Determination of water-soluble chloride content of fresh mortars.
Part 18	Determination of water absorption coefficient due to capillary action of hardened mortar.
Part 19	Determination of water vapour permeability of hardened rendering and plastering mortars.
Part 21	Determination of the compatibility of one-coat rendering mortars with substrates.

**Table 1 : BS EN 1015 - Methods of Test for Mortar for Masonry**

Each of the individual parts of the Standard will be considered in turn.

### General Requirements

- i) There is a requirement in several parts of the Standard that ready-to-use mortars shall be tested within their specified working life.
- ii) Several parts of the Standard have a requirement that the minimum volume of the sample of fresh mortar shall be at least 1.5 litres or 1.5 times the volume (whichever is the greater) needed to perform the test.
- iii) Prior to testing samples of fresh mortar they should be gently stirred by hand for five to ten seconds with a palette knife.
- iv) Where moulds/sample containers are filled with fresh mortar they should be filled to overflowing and the excess struck off with a palette knife.

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- v) Bulk samples may be reduced in size by the use of sample dividers or coning and quartering, the learning text on aggregates provides more detailed information on this subject.

### **Determination of Particle Size Distribution (By Sieve Analysis): BS EN 1015-1**

This part of the Standard prescribes the procedure for determining the particle size distribution of dry mixed or non hardened mortar or non hardened wet mixed mortar. The test is undertaken by placing individual sieves on top of each other to form what is called a “nest” of sieves (Figure 1). Table 2 lists the sieves that should be used:

Sieve Aperture size - mm
8.00
4.00
2.00
1.00
0.500
0.250
0.125
0.063

**Table 2 : Sieves required for mortar testing**



**Figure 1 : A nest of sieves**

The test sample is placed in the top sieve of the nest and the sieves are agitated until material ceases to pass each of the sieves, the mass of material retained on each sieve is then determined. The Standard describes two alternative methods of undertaking sieve analysis, wet sieving and dry sieving. Where wet sieving is undertaken water is poured over the test sample in a container. This is then mixed and poured into the top sieve of the nest, a cover is then placed over the top sieve and the nest agitated, each sieve and its residue is gently washed with a jet of water to ensure no undersize material remains on the sieve. When material ceases to pass each sieve the material is removed and placed on individual trays and dried in an oven at  $105 \pm 5^{\circ}\text{C}$  until a constant mass is obtained.

Where dry sieving is to be undertaken the material is dried in an oven at  $105 \pm 5^{\circ}\text{C}$  until a

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constant mass is obtained, prior to undertaking the sieve analysis. The Standard prescribes that mortars containing lightweight material shall only be tested by the dry sieving method.

### **Bulk sampling of mortars and preparation of test mortars : BS EN 1015-2**

The sampling of any material is very important, if a sample is not representative of the material the test results will be invalid. The taking of samples may involve sampling from moving conveyors, trucks or delivery vehicles. It is essential that all health and safety requirements be complied with to minimize the risk of accidents. This includes wearing the appropriate personal protective equipment.

i) Sampling from mixers

A minimum of three increments is taken by passing the sample receptacle across the stream of mortar being discharged from the mixer.

ii) Sampling from conveyors

The sample is taken at the discharge point of the conveyor by passing the sample receptacle across the stream of mortar at the discharge point. Where it is not possible to sample the discharge stream in one operation take a number of increments. An alternative method of sampling is to stop the conveyor, isolate the plant equipment and use a scoop to sample the full width of the conveyor belt. Where sample increments are taken, not less than three increments should be taken.

iii) Sampling from hoppers

Where possible hoppers are sampled when they are being filled or during discharge, this is especially important with large hoppers, if this is not possible take a minimum of three increments from at least 100 mm below the surface. It is very important for safety reasons that the person taking the sample never enters the hopper.

iv) Sampling from delivery vehicles

Samples are where possible taken when the vehicle is being filled, if this is not possible and samples have to be taken from a full vehicle take the sample in the same manner as used for sampling from hoppers.

Sampling may result in a number of increments being taken, these are combined and thoroughly mixed on an impervious surface to form a bulk sample. The bulk samples may be reduced in size to produce a test sample by taking increments at random places from the mixed material and recombining these.

The Standard lists the information that must be recorded to produce a sampling certificate. This part of the Standard also prescribes how dry mortars should be mixed to prepare wet test samples.

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### **Determination of Consistence of Fresh Mortar (by flow table): BS EN 1015-3**

The flow value is determined by measuring the mean diameter of a test sample. The bulk sample of fresh mortar is reduced to a minimum sample size of 1.5 litres. Where it is desired to measure the flow of dry mortars these should be mixed with water in accordance with the requirements of BS EN 1015-2.

The test procedure involves placing the mould (60 mm in height, internal diameter: base 100 mm - top 70 mm) in the center of the flow table and filling it in two layers each layer being tamped ten times with the tamper. It is important that the mould is held firmly in place during this operation. The excess mortar is removed from the top of the mould with the palette knife and the area around the base of the mould cleaned with a cloth. A period of approximately 15 seconds is allowed to elapse and the mould is then removed, the table is jolted 15 times at a rate of one jolt per second. The diameter of the spread mortar is measured in two directions at right angles to each other using calipers, both results are reported.

### **Determination of Consistence of Fresh Mortar (by plunger penetration): BS EN 1015-4**

This part of the Standard lists a second method of measuring consistence, for an individual mortar it is normally possible to derive a correlation with the flow table method. The principle of this method is that a plunger rod having a mass of 90 grams is allowed to fall from a height of 100 mm above the mortar. A sample of fresh mortar is placed in a cylindrical vessel in two layers, each layers being compacted with 10 strokes of the tamper (identical specification to the tamper used for the flow table test). The cylindrical vessel is placed under the plunger stand and the plunger allowed to fall from a height of 100 mm above the surface of the mortar, the depth of penetration is read from a scale on the plunger and recorded to the nearest millimeter.

### **Determination of Bulk Density of Fresh Mortar : BS EN 1015-6**

The bulk density of mortar is determined by calculating the mass of mortar contained in a known volume. A sample of fresh mortar with a minimum volume of 3 litres (or at least 1.5 times the volume need to perform the test). Three different methods of filling and compacting the mortar within the calibrated container which should have a volume of approximately 1 litre are given are in the Standard, (the container used for determining the air content of fresh mortar is suitable). The method to be used depends upon the consistence of the fresh mortar as determined by the flow table test

i) Flow value less than 140 mm (stiff mortar) - Vibration method

The calibrated container is filled with mortar using a scoop until it is overflowing it is then placed on a vibrating table and vibration continued until no further settlement of the material is observed, extra material is added if necessary. The container is then weighed to an accuracy of 1 gram.

ii) Flow value between 140 mm and 200 mm (Plastic mortar) - Shock method

The calibrated container is filled to approximately half its height with mortar using a scoop, the container is then tilted about 30 mm on alternate sides and allowed to fall

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ten times on to a solid base. Where the mortar contains an air entraining admixture the number of shocks is reduced to five. The container is then filled to overflowing and the shock compaction repeated. The container is then weighed to an accuracy of 1 gram.

iii) Flow value greater than 200 mm (Soft mortar)

The calibrated container is filled with mortar using a scoop until it is overflowing, the edges of the container are wiped clean with a damp cloth and the container weighed to an accuracy of 1 gram.

The bulk density ( $\rho_m$  in  $\text{kg/m}^3$ ) is calculated by use of the formula:

$$\rho_m = (m_2 - m_1) / V_v$$

$m_1$  = mass of empty container

$m_2$  = mass of container plus mortar

$V_v$  = volume of container

### Determination of air content of fresh mortar : BS EN 1015-7

Two methods are prescribed for measuring the air content of fresh mortar, the pressure and the alcohol method. The pressure method is applicable for mortars with an air content less than 20%, the alcohol method is applicable to mortars with an air content greater than 20%.

i) Pressure method

The equipment consists of a sample container and a cover assembly, the container has an approximate volume of 1 litre, (the equipment is shown in Figure 2) a tamper (identical specification to the tamper used for the flow table test, BS EN 1015-2) and a palette knife are also required.



**Figure 2 : A pressure type air meter**

The sample container is filled in four approximately equal layers, each layer is compacted with ten strokes of the tamper, the palette knife is used to remove any



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excess mortar. The container is cleaned with a damp cloth, (the rim of the container should be free of any adhering mortar otherwise a watertight seal may not be achieved) and the cover assembly clamped in position and the main air valve closed. Water is introduced through valve A (used to fill the container with water) until all the air is expelled through valve B (this allows the escape of air from the container). Air is pumped into the air chamber until a stabilized condition is reached, this is equal to the level determined during the calibration procedure. Valves A and B are closed and the valve between the air chamber and the sample container is opened. When equilibrium is reached the air content is read from the pressure gauge. The actual air content is determined from the calibration curve and recorded to the nearest 0.1%. The calibration procedure involves obtaining a correlation between pressure and air contents over the range 5-25%.

It should be noted that Annex A of BS EN 1015-7 contains a schematic diagram of the apparatus.

### ii) Alcohol method

This test method involves filling a 500 ml graduated measuring cylinder with approximately 200 ml of fresh mortar, the measuring cylinder is tapped to level the mortar and the volume recorded to the nearest ml ( $V_{m1}$ ). A mixture of 60% ethyl alcohol and 40% water is added until the 500 ml mark is reached, a rubber bung is inserted in the top of the cylinder and the cylinder inverted twenty times. The mixture is allowed to settle for five minutes and the level of the surface ( $V_{mf}$ ) is then recorded to the nearest ml.

The air content is calculated by use of the formula:

$$L = \frac{(500 - V_{mf})}{V_{m1}}$$

and reported to the nearest 0.1%.

Both methods of determining the air content require that two individual tests are undertaken and the mean value reported. The individual results are required to be within 10% of the mean value reported otherwise the test procedure has to be repeated. The Standard also requires that the flow value be reported.

## Determination of Workable Life and Correction Time of Fresh Mortar: BS EN 1015-9

This part of the Standard contains three test methods:

- Method A- Workable life of general purpose mortar
- Method B- Workable life of thin layer mortar
- Method C- Correction time of thin layer mortar.

The Standard requires that the flow value of the mortar to be tested shall be determined.

### i) Method A - Workable life of general purpose mortar

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The workable life of the fresh mortar is defined as the time measured in minutes at which the mortar exhibits a defined limit of resistance to the penetration of a standard rod forced into it. The test procedure involves filling a number of moulds (internal diameter 75 mm and 50 to 100 mm high) with fresh mortar and measuring the penetrative force.

The equipment required is a penetration rod with a diameter of 5 mm and an approximate length of 65 mm, the lower 25 mm of the rod should have a diameter of 6.175 mm and the end face of the rod should be flat. A brass washer of approximately 20 mm diameter and an internal diameter such that the washer is held at the point of the change in diameter of the rod. The penetration rod is held in a drill stand that allows the rod to be lowered over a minimum distance of 40 mm.

The moulds are filled in ten increments and each mould tapped four times on a solid base after the addition of each increment. The moulds are stored at an air temperature of  $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$  and at a relative humidity of 95%.

The moulds are placed on a weighing scale (minimum capacity 15 kg and maximum graduations 100 g) situated under the penetration rod. The scale reading is noted ( $R_1$ ) and the penetration rod slowly lowered into the fresh mortar, (care should be taken that the point of contact is at least 20 mm from the mould edge or from a previous point of contact with the fresh mortar. The reading on the scale is noted ( $R_2$ ), the increase in mass ( $R_1 - R_2$ ) divided by three should be reported as the resistance to penetration.

The penetration resistance of non-retarded mortars is measured at intervals of fifteen minutes commencing thirty minutes before the expiry of the declared workable life. Measurements are continued until the prescribed limit of resistance is reached. For retarded mortars the penetration is measured at intervals until it starts to increase and measurements continued until the prescribed limit of resistance is reached.

The time in minutes reported to the nearest minute to give a resistance of penetration of  $0.5\text{ N/mm}^2$  is reported as the workable life. (It will normally be necessary to determine this value by interpolation).

### ii) Method B - Workable life of thin-layer mortar

The workable life is measured by the time taken in minutes for the flow value to differ by more than 30 mm from the flow value measured 10 minutes after the mortar is mixed. The fresh mortar is maintained at an air temperature of  $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ . The test procedure requires that the flow value is determined at intervals of 15 minutes and the point at which a difference in flow of 30 mm occurs is determined by interpolation.

### iii) Method C - Correction time of thin-layer mortar

The correction time of thin-layer mortar is defined as the time in minutes at which 50% of the contact surface of a cube placed on a layer of mortar applied on the specified masonry substrate and then removed is covered with adhering mortar.

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The test procedure involves cutting cubes with dimensions 50 mm x 50 mm x 50 mm from the specified masonry unit. Prior to performing the test the cubes and masonry units are dried. The drying temperature depends on the composition of the masonry units (Table 1 in BS EN 1015-9 lists the requirements). A cycle of drying and weighing is maintained until two consecutive readings taken at an interval two hours apart do not differ by more than 0.2% by mass.

The masonry units are then stored at a temperature of  $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$  and at a relative humidity of  $65\% \pm 5\%$  for two days, testing is then carried out under the same conditions. Mortar is applied to the masonry units with a trowel and then swept off, following this a layer of mortar 2 - 3 mm thick is then applied. A cube is then brought into contact with the mortar and maintained in position for thirty seconds, a load (the actual load depends on the density of the mortar unit) is maintained on the cube during this period. The cube is removed and the area covered with mortar determined. This procedure is repeated at intervals of one minute until 50% of the cube contact area is covered with adhering mortar.

### Determination of Dry Bulk Density of Hardened Mortar : BS EN 1015-10

A sample of fresh mortar of minimum volume 50 times greater than the maximum aggregate size (or 1.5 times the quantity needed to perform the test) whichever is the greater is required. Three test samples of regular shape are prepared from the fresh mortar to be tested and cured in accordance with BS EN 1015-11. The hardened test samples are dried to a constant mass at a temperature of  $70^{\circ}\text{C}$  (where organic material is incorporated a maximum temperature of  $65^{\circ}\text{C}$  is used), the dry mass is recorded to the nearest 0.1% ( $m_{\text{dry}}$ ).

The test specimens are immersed in water (temperature  $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ), the mass is noted after a period of immersion and the process repeated until the saturated mass does not differ by more than 0.2%. The saturated mass is recorded to the nearest 0.1% ( $m_{\text{sat}}$ ). The volume of the test specimens is now determined by weighing the test specimens in water (using a stirrup attachment to the balance), the mass of the immersed test specimens is recorded to the nearest 0.1% ( $m_i$ ).

The volume is calculated by use of the formula:

$$V_s = (m_{\text{sat}} - m_i) / \text{Density of water kg/m}^3$$

The bulk dry density of each test specimen is calculated from the volume:

$$\frac{\text{Dry density } (m_{\text{dry}})}{\text{Volume}}$$

The mean dry density of the three test samples is required to be recorded to the nearest  $10 \text{ kg/m}^3$

### Determination of Flexural and Compressive Strength of Hardened Mortar: BS EN 1015-11

The flexural strength of a hardened mortar is determined by three point loading of a prism specimen, subsequent to the failure and breakage of this specimen the compressive strength is determined on each half of the prism. Prism mould compartments are required to be 160 mm x 40 mm x 40 mm (each mould assembly produces three prism specimens), prior to use they

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are lubricated with a thin layer of mineral oil. Depending on the type of binder different procedures are applicable for the manufacture of the prisms.

- i) Mortars produced from hydraulic binders and air-lime binders where the mass of air-lime is not greater than 50% of the total binder content:

The mould is filled in two layers each layer being compacted with twenty five strokes of the tamper. (Tamper: a rigid non-absorptive rod, with a square cross section of 12 x 12 mm and a mass of 50 grams).

- ii) Mortars produced from air-lime and air-lime cement binders with a cement mass less than 50% of the total binder content:

The mould is placed on a glass plate, on which two layers of white cotton gauze have been placed, the mould is filled and compacted as described in i). Two layers of cotton gauze are placed on top of the compacted prisms followed by six layers of absorbent filter paper. A glass plate is placed on top of the mould and the whole assembly inverted, the glass plate is then carefully removed and six layers of filter paper placed on top of the gauze and the glass plate replaced. The wholly assembly is then re-inverted and an approximate mass of 5 kg placed on top of the glass plate and the assembly left undisturbed for a period of three hours. At the end of this period the top glass plate is removed and the filter paper and gauze discarded. The glass plate is then replaced, the assembly inverted, the glass plate is removed and the gauze and filter paper discarded. The test specimens are then cured.

Initial curing may be carried out either in a polythene bag or in a curing chamber, part of the initial curing period is undertaken with the test specimen removed from the mould.

The main curing period is undertaken in a curing chamber, Table 1 in BS EN 1015-11 lists the time periods for the different stages of curing which are dependent on the type of binder used.

The determination of flexural strength is undertaken when the test specimens are twenty-eight days old, the testing machine is required to have two supporting rollers and a third roller (the loading roller, located above the test specimen and midway between the supporting rollers). The prism is placed so that one of its faces, which has been cast against the steel mould, is in contact with the supporting rollers. The load is applied to the test specimens at a rate that produces failure in a time period of thirty to ninety seconds. The flexural strength ( $f$ ) is calculated from the equation:

$$f = 1.5 \frac{Fl}{bd^2}$$

Where  $b$  and  $d$  are the internal dimensions of the prism mould,  $l$  is the distance between the supporting rollers. The result is recorded to the nearest  $0.05 \text{ N/mm}^2$  and the average of the set of results reported to the nearest  $0.1 \text{ N/mm}^2$ .

The compressive strength is determined on the broken halves of the prism by using a compression jig in a testing machine care being taken that the load is applied to a face cast against the steel face of the mould. The load is applied to the test specimens at a rate that

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produces failure in a time period of thirty to ninety seconds. The compressive strength is recorded to the nearest  $0.05 \text{ N/mm}^2$  and the mean result reported to the nearest  $0.1 \text{ N/mm}^2$ .

### **Determination of Adhesive Strength of Hardened Rendering and Plastering Mortar on Substrates: BS EN 1015-12**

This test method involves determining the maximum tensile stress applied by a direct load at right angles to the surface of the rendering. Where the rendering mortar is designed for use with a particular type of masonry, it is tested with samples of the appropriate masonry. If no specific background (substrate) is specified, concrete panels with minimum dimensions  $550 \text{ mm} \times 150 \text{ mm} \times 50 \text{ mm}$  (thickness) are used. The panels are prepared from concrete with a water cement ratio of 0.55 and graded aggregates with a maximum particle size of one third of the panel thickness. The concrete panels are wood floated to provide a suitable surface and are required to be at least twenty eight days old when testing is undertaken.

The fresh mortar that is to be tested is applied to the relevant substrate to achieve a thickness of  $10 \text{ mm} \pm 1 \text{ mm}$ . Two options exist for sampling the test specimen. Firstly, a sample may be obtained after initial setting of the mortar by pressing the sharp edge of a lightly oiled truncated conical metal ring (internal diameter 50 mm and 25 mm high) into the mortar until the substrate is reached. Secondly, a sample may be obtained where it is hardened by using a core drill with a similar internal diameter and drilling into the mortar and substrate. (Drilling should be to a depth of 2 mm into the substrate).

The test specimens are stored in an airtight polythene bag at a temperature of  $20^\circ \text{ C} \pm 2^\circ \text{ C}$  for seven days and then for twenty one days in a humidity chamber at a similar temperature and a humidity of  $65\% \pm 5\%$ . The test specimens are tested immediately on removal from the humidity chamber.

The pull head is glued (the adhesive should be epoxy resin or methyl methacrylate resin) to the mortar surface care being taken to prevent the adhesive bridging the cut area. The testing machine is connected to the pull head and a perpendicular tensile load applied, the failure load is recorded, the rate of application of the load depending on the anticipated adhesive strength, Table 2 of BS EN 1015-12 lists the requirements. Five test specimens are used, the individual adhesive strengths are recorded to the nearest  $0.05 \text{ N/mm}^2$  and the mean value to the nearest  $0.1 \text{ N/mm}^2$ .

The Standard incorporates three figures illustrating the type of fracture pattern that can occur:

- Fracture at the interface between the mortar and substrate.
- Fracture within the mortar.
- Fracture in the substrate material.

### **Determination of Water-Soluble Chloride Content of Fresh Mortar: BS EN 1015-17**

This is the only chemical test method within the BS EN 1015 series of Standards. The test method is based on the formation of a soluble coloured compound, this analytical technique is sometimes referred to as the Volhard method, named after the chemist who developed it in 1878. The principle of this analytical technique is that the chloride solution is treated with an

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excess of silver nitrate and the residual silver nitrate determined by titration with ammonium thiocyanate. The chloride ion present in the test sample reacts with the silver nitrate to form silver chloride, the titration with ammonium thiocyanate allows the analyst to determine how much silver nitrate has reacted.

The sample has to be in a dry state, where a sample of fresh mortar has been taken this is dried in an oven at a temperature of  $105^{\circ}\text{C} \pm 5^{\circ}\text{C}$ , the sample is then ground to pass through a 0.125 mm test sieve. The water soluble chloride is extracted by placing a 10 gram sample in a polythene bottle and adding 100 ml of distilled or deionized water. The sample is shaken for approximately 60 minutes and then allowed to stand for a minimum period of 15 hours and a maximum period of 24 hours.

The sample is then filtered, 20 ml of dilute nitric acid is added to the filtrate and the solution is boiled. To the boiling solution 5 ml of silver nitrate solution is added and after a further 2 minutes boiling the solution is cooled to below  $25^{\circ}\text{C}$ . A chemical indicator is then added to the solution and ammonium thiocyanate is added drop wise from a burette until a permanent reddish brown colour is obtained, the quantity added is recorded. The volume of silver nitrate that has reacted is calculated and by the use of a chemical formula the chloride content of the sample is determined. The Standard gives details of the concentration (molarity) of the chemical solutions that should be used.

### **Determination of Water Absorption Coefficient Due to Capillary Action of Hardened Mortar: BS EN 1015-18**

This test procedure is undertaken using mortar prism specimens that are dried to a constant mass, one face of the prism is immersed in water for a specified period of time and the increase in mass is determined. A prism mould (see section on BS EN 1015-11) is lined at the base with absorbent filter paper and filled with fresh mortar, the top surface is also covered with a layer of filter paper. The test specimens are then cured for an initial period, part of the initial curing period is undertaken with the specimen removed from the mould. The main curing period is undertaken in a curing chamber. Table 1 of BS EN 1015-18 lists the time periods for the different stages of curing which are dependent on the type of binder used.

At the completion of the curing period of the test specimens the long faces are sealed with paraffin wax (or a synthetic reactive resin with a melting point above  $60^{\circ}\text{C}$ ) and are then broken into half. The test specimens are then dried in an oven at  $60^{\circ}\text{C} \pm 5^{\circ}\text{C}$  until two successive weighings undertaken twenty four hours apart give a mass variation of less than 0.2% of the total mass.

The test specimens are placed broken end downwards on four support pads (these should have as small an area as possible) in a tray (having a minimum depth of 20 mm). The test specimens are immersed to a depth of 5-10 mm in water and the tray covered to minimize evaporation. The time of immersion is noted

The procedure now varies, for renovation mortars a modified procedure is followed. The test specimens (all mortars except renovation) are removed from the tray after ten minutes. The surface water is wiped off with a damp cloth and the mass determined, the test specimens are replaced in the tank and the mass determined using the same procedure after ninety minutes. Where renovation mortars are being tested the test specimens are immersed for a twenty four

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hour period, on removal from the tray they are weighed, they are then split along the long dimension and the depth of water penetration measured to the nearest 1 mm.

The coefficient of water absorption is calculated using the appropriate formulae given in the Standard.

### **Determination of Water Vapour Permeability of Hardened Rendering and Plastering Mortars: BS EN 1015-19**

The procedure for this test method involves the production of disc shaped specimens that are then exposed to water vapour pressure, the rate of moisture transfer is determined by the change in mass. The test specimens are produced by applying a layer of mortar (10-30 mm thick and slightly larger in diameter than the cups) to a substrate of aerated concrete (density  $550 \text{ kg/m}^3 \pm 50 \text{ kg/m}^3$ ), prior to the application of the mortar place two layers of cotton gauze on the substrate. Five test specimens are prepared for each hygroscopic range. The test specimens are cured for a total period of twenty eight days, Table 1 of BS EN 1015-19 lists the requirements for the initial curing period and the main curing period, the requirements depend upon the type of binder used.

At the end of the curing period the specimens are cut to the dimensions of the test cups (the test cups should be made of corrosion resisting material and have an area of approximately  $0.02 \text{ m}^2$ ). The test specimens are then placed in the test cups and the edges sealed with an impermeable sealant, which remains constant in mass under the test conditions. The cups are manufactured so that the test specimen is held on a ledge below which the chemical solution is placed there must be an air gap of  $10 \text{ mm} \pm 5 \text{ mm}$  between the test specimen and the chemical solution (Figure 1 in the Standard provides an illustration). The test cups are placed in the curing chamber at a temperature of  $20^\circ\text{C} \pm 2^\circ\text{C}$  and at a relative humidity of  $50\% \pm 5\%$ .

The test cups are weighed at intervals and a graph drawn plotting time against mass, if three points can be placed on a straight line the quantity of water vapour passing through the test specimen is taken to be constant. A formula is given in BS EN 1015-19 to calculate the water vapour permeability

Two hygroscopic ranges are tested. Samples are prepared in exactly the same way but different chemical solutions are used. A saturated solution of potassium nitrate provides a relative humidity of 93.2% and a saturated solution of lithium chloride provides a relative humidity of 12.4% at a temperature of  $20^\circ\text{C} \pm 2^\circ\text{C}$ .

### **Determination of The Compatibility of One-Coat Rendering Mortar with Substrates: BS EN 1015-21**

This test method evaluates the compatibility of one coat rendering mortar with a given substrate, the samples are brought to a standard condition and then subjected to two tests, which evaluate the water permeability and the adhesion strength. The test specimen is prepared on either a concrete substrate (minimum dimensions 300 mm x 300 mm x 40 mm) or on a masonry substrate (minimum dimensions 400 mm x 400 mm made from at least one whole and two half masonry units). The fresh mortar is applied to the vertical substrate, two test panels are produced one with a mortar thickness of 10 mm and the other 20 mm. The test specimens are cured for a minimum of twenty eight days at a temperature of  $20^\circ\text{C} \pm 2^\circ\text{C}$  and a

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relative humidity of  $65\% \pm 5\%$ . The test specimens are then subjected to a two stage conditioning process.

On completion of curing the test specimens are firstly subjected to four heating and freezing cycles. The test specimens are heated by an infrared lamp to a temperature of  $60^{\circ}\text{C} \pm 2^{\circ}\text{C}$  for a period of eight hours, they are then placed in the standardized curing conditions for thirty minutes. Following this the samples are placed in a deep freeze cabinet (temperature  $-15^{\circ}\text{C} \pm 1^{\circ}\text{C}$ ) for fifteen hours, the test specimens are then placed in the standardized curing conditions for thirty minutes. The cycle is repeated four times, after completion of the fourth cycle the test specimens are placed in the standardized curing conditions for a minimum of forty eight hours.

The second stage of the conditioning process is then undertaken. The test specimens are partially immersed in water (temperature  $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ), with the rendered sides in the water to an approximate depth of 5 mm for a period of eight hours. They are then placed in the standardized conditions used for curing for thirty minutes. Following this the samples are placed in a deep freeze cabinet (temperature  $-15^{\circ}\text{C} \pm 1^{\circ}\text{C}$ ) for fifteen hours, the test specimens are then placed in the standardized curing conditions for thirty minutes.

During each stage of the conditioning cycle the test specimens are examined for any signs of damage and a record made of any deterioration.

The test specimens are then tested for water permeability, prior to undertaking this test the test specimens are maintained in the standard curing conditions for forty eight hours (Figure 1 of BS EN 1015-21 illustrates the test apparatus). A metal cone with a base diameter of 200 mm and a height of 100 mm is required to be bonded to the rendered surface of the test specimen using a water resistant sealant. A head of water of 100 mm above the surface is maintained for a period of forty eight hours, the quantity of water required to maintain this head is recorded to the nearest 1 ml. The water permeability is calculated as the quantity of water required to maintain a constant level divided by  $100\pi$ ,  $\text{ml}/\text{cm}^2$ , the result is reported as  $\text{ml}/(\text{cm}^2 \cdot 48 \text{ h})$  to the nearest 0.1  $\text{ml}/\text{cm}^2 \cdot 48 \text{ h}$ .

Following completion of the water permeability test the test specimens are placed in the standard curing conditions for a minimum of four days, the adhesive strength is then determined and reported in accordance with the requirements of BS EN 1015-12.

### **BS 4551 : Methods of Test for Mortar**

Historically this Standard has been published in two parts, Part 1 covered the physical tests and Part 2 the chemical tests. This Standard has now been revised and published as a single document. The majority of the physical tests for mortar for masonry are covered by BS EN 1015, the two exceptions are:

- Determination of consistence by dropping ball
- Determination of consistence retentivity and water retentivity.

The Standard also covers the chemical tests for mortar, which have not yet been addressed within the European standardization programme.



### Determination of Consistence by Dropping Ball

This test method determines the penetration of a ball made of methyl methacrylate into a test sample of fresh mortar when dropped from a prescribed height. A mould made of rigid material (internal diameter 100 mm, height 25 mm) is filled with fresh mortar in approximately ten increments pushing the mortar into the mould with the palette knife, the excess mortar is struck off with a palette knife. The ball is held in a mechanism and dropped from a height 250 mm above the test specimen, the ball mechanism is positioned so that the ball falls in the approximate centre of the fresh mortar ( $\pm 12$  mm). The penetration of the ball is measured to the nearest 0.1 mm using the measuring device. Three separate determinations of penetration are made and the mean value reported.

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### Determination of Consistence Retentivity and Water Retentivity

This test procedure determines the change in the level of consistence when the mortar is subjected to suction and the loss of water from the fresh mortar. The mould (as described in the previous section) is weighed, eight discs of filter paper are also weighed. The consistence by dropping ball is then determined, the depression left by the penetration is filled and the fresh mortar struck off with the palette knife. The mould and its contents are then weighed. Two pieces of cotton gauze and the eight discs of filter paper are placed on top of the mortar and a non porous plate is placed on top of these together with a 2 kg weight. A period of two minutes is allowed to elapse, the weight and plate removed, the cotton gauze discarded and the filter papers weighed to the nearest 0.05 grams.

The mass of water remaining in the mould (i.e. the mass of water originally in the mortar minus the water absorbed by the filter paper) is expressed as a percentage of the original water content of the fresh mortar and reported as the water retentivity. The original water content may be determined as described in the next section.

Any fall in the level of the mortar in the mould is measured and recorded, the penetration determined by the dropping ball should again be undertaken. A correction is made for any measured fall in level (subtract the fall in level from the penetration depth). The corrected penetration is reported as a percentage of the penetration before suction as the consistence retentivity. The determination is repeated and the mean water retentivity reported to the nearest 1%, the mean consistence retentivity is reported to the nearest 5%.

### Free Water Content

The free water content is determined by weighing a  $10 \pm 1$  gram sample into a tared dish and drying in the oven at  $105^{\circ}\text{C} \pm 5^{\circ}\text{C}$  until a constant mass is obtained. The free water content is reported as the loss in mass expressed as a percentage of the original wet mass.

### Available Lime Content

A  $5 \pm 0.05$  gram sample is weighed into a 250 ml conical flask containing 30 ml of distilled water, the flask is stoppered and swirled, the stopper is loosened and the contents heated to boiling and the flask then allowed to simmer for two minutes. The flask is then removed from the heat source, 150 ml of water and 15 grams of granulated sugar added. The flask is stoppered and shaken vigorously and allowed to stand for a minimum period of thirty minutes and a maximum period of one hour.

A chemical indicator is then added and the solution titrated with hydrochloric acid until the colouration disappears. The Standard gives details of the concentration of the acid solution and the formula for calculating the available lime content.

### Other Chemical Tests

The Standard also prescribes how a range of more complex chemical tests are undertaken:

- insoluble residue,
- soluble silica,
- calcium oxide,
- sulfur trioxide,

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- total iron,
- aluminium oxide,
- magnesium oxide.

To undertake these tests accurately and safely specialist training in analytical techniques is required and therefore they are not discussed further in this learning text. Chemical analysis requires the use of very small sample sizes and even greater care must be taken when sampling mortars for these techniques.

### Glossary of terms

- Bulk sample** - A sample comprising a mixture of all the individual increments taken.
- Burette-** - A graduated glass tube with a tap for measuring the volume of liquid run out from it.
- Chemical Indicator** - A substance that by a sharp colour change indicates the completion of a chemical reaction.
- Consistence** - The fluidity of a fresh mortar.
- Density** - The mass per unit volume of a substance.
- Bulk Density** - The density of a porous or granular material calculated per unit volume of the substance including pores or spaces, it is less than the true or absolute density of the material.
- Filtrate** - A substance that has been filtered and contains no suspended matter.
- Hygroscopic** - A material that has a tendency to absorb moisture.
- Increment** - Quantity of material taken in a single operation of the sampling equipment used.
- Molarity** - A method of expressing the strength of a chemical solution.
- Relative Humidity** - Humidity is the amount of moisture in the air, there are various methods of measuring and reporting it. The most common format is relative humidity- this is the amount of water vapour present in the air expressed as the amount of water vapour that the air can hold at that temperature. Because temperature greatly affects water vapour, air that has only a 30% relative humidity at 30°C has 100% relative humidity at 10 °C. At 100% relative humidity dew would form on the ground.
- Renovation Mortar** - A designed rendering/plastering mortar for use on moist masonry walls containing soluble salts. These mortars have a high porosity and vapour permeability and reduce capillary action.
- Saturated Solution** - A solution where no material can be dissolved at that temperature.

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**Thin-layer Mortar** - A designed masonry mortar for use in joints between 1 and 3 mm thick, with a maximum aggregate size less than or equal to 2 mm.

**Titration** - The addition of a measured amount of one reagent to a definite amount of another reagent until the reaction between them is complete. (until the second reagent is completely used up).

### Self-Assessment Questions

- 1 What two Standards are concerned with mortar testing?
- 2 What is the minimum number of sample increments that should be taken?
- 3 What are the three methods of determining consistence?
- 4 How is the bulk density of fresh mortar calculated?
- 5 Which method of measuring air content should be used for a mortar with an air content greater than 20%?
- 6 Which are the two main chemical reagents used in the determination of water soluble chloride?
- 7 How is the correction time of thin-layer mortar defined?
- 8 What test method is used to determine the workable life of thin-layer mortar?
- 9 What type of test specimens are used to determine the compressive strength of mortar?
- 10 How is relative humidity defined?

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## Answers to Self-Assessment Questions

- 1 BS EN 1015 - Methods of test for mortar for masonry.  
BS 4551 - Methods of test for mortar.
- 2 3
- 3 Flow table  
Plunger penetration  
Dropping ball.
- 4 The bulk density is calculated by dividing the mass of material by the volume it occupies.
- 5 The alcohol method should be used for measuring air contents greater than 20%.
- 6 Silver nitrate and Ammonium thiocyanate.
- 7 The correction time of thin-layer mortar is defined as the time in minutes at which 50% of the contact surface of a cube placed on a layer of mortar applied on the specified masonry substrate and then removed is covered with adhering mortar.
- 8 The flow table test.
- 9 The two broken parts of a prism.
- 10 Relative humidity is expressed as a percentage, 100% relative humidity means that the air is saturated or completely full of water. The higher the temperature the greater the quantity of water vapour the air can hold.